AN EXTERNALLY COATED PYREX G-M COUNTER

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ABSTRACT. A Geiger-Muller counter, using an externally coated pyrex envelope, is reported as possessing a plateau of more than 1600 volts. Some other properties of this counter are also described, together with a tentative explanation of its characteristics.

INTRODUCTION

The Geiger-Muller counter, being one of the most sensitive detectors of radiation, is needed in many branches of scientific research. In view of this, various attempts have been made in the past to improve the technique of production, so that a large number of reliable counters can be easily and cheaply made available to scientific workers.

Rochester and Janossy (1943) reported preparation of counters which had not been chemically treated and which were quite efficient for coincidence work. In order to obtain a better geometry, all-metal counters have been widely reported (Korff, 1943 ; Neher, 1946 ; Regener, 1947) but they involve many technical problems. Internal coating of glass tubes by copper evaporation method has been practised in some laboratories (De Vos and Du Toil, 1945) and since it obviates the necessity of surface oxidation, it can be considered a definite step forward in the development of Geiger counter production techniques. However, an internal coating of some conducting paint, such as commercial aquadag, is just as efficient as an evaporated layer of copper, and for this reason aquadag-coated' counters are at present widely employed. In fact, in order to make the construction still simpler, Maze (1946) reported the use of soft glass with an external coating of conducting material. These counters were found to have a plateau of as much as 400 volts and a slope which was less than that of internal cathode counters.

In this laboratory, since we were faced with the problem of manufacturing a large number of rugged but reliable counters under the circumstances that metal tubing itself is hard to obtain, work was undertaken to further improve the techniques of counter production. At first, soft glass tubes were coated by commercial aquadag and the G-M counters so produced were found to be highly photo-active. This defect was removed by painting the entire counter with a non-conducting black paint. Further, in order to study the effect of the material of the counter envelope, some pyrex tubes were similarly prepared and they exhibited the properties mentioned below.

Plateau and Slope

Conventional G-M counters are considered to be very satisfactory if they have a plateau of about 300 volts, and a slope of 1 to 2% per 100 volts. In the case of externally coated pyrex G-M counters, the threshold potential was found to be slightly higher than that of comparable internal cathode counters, but the plateau was found to be nearly five times longer. In some carefully prepared tubes, the plateau turned out to be even 2000 volts, and it had a slope of less than 0.4% per 100 volts. The characteristics of conventional and new type of counters are shown in Fig. 1 and it is obvious that the plateau and slope of the latter are superior to those of the former.

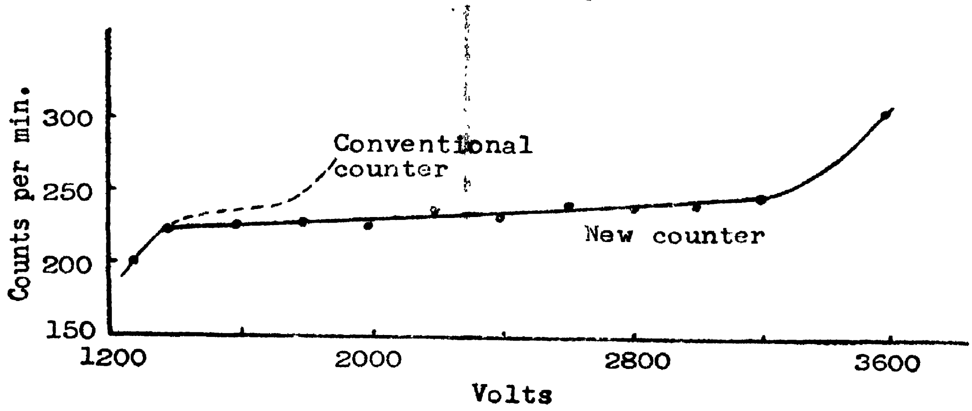

FIG. 1

The plateau characteristic of an externally coated pyrex counter: argon and alcohol 9 and 1 cm of mercury respectively, internal diameter 23 mm, external diameter 36 mm, 7 mil central tungster wire, observed plateau 1800 volts, slope better than 0.4% per 100 volts.

Threshold voltage and pulse size

As stated above, under normal operating conditions, due to the presence of glass between the anode and cathode, the threshold potentials of these counters are generally higher than those of conventional counters of similar dimensions and gas pressure. The threshold voltage appears to increase if the number of counts that have to be recorded increases. This apparent change of threshold voltage is due to the fact that there is a decrease in pulse size if the rate of counting is high. This does not, however, affect the length and the slope of the plateau, which under these conditions, extend to higher voltages. It is obvious that when the size of the pulses diminish beyond the minimum amplitude necessary for operating the scaler, the number of counts recorded by the system goes down, and in order to restore counting, the applied voltage has to be increased. Fig. 2 shows the variation of pulse size and threshold voltage with the number of counts that have to be recorded. This figure shows that even when the rate of counting

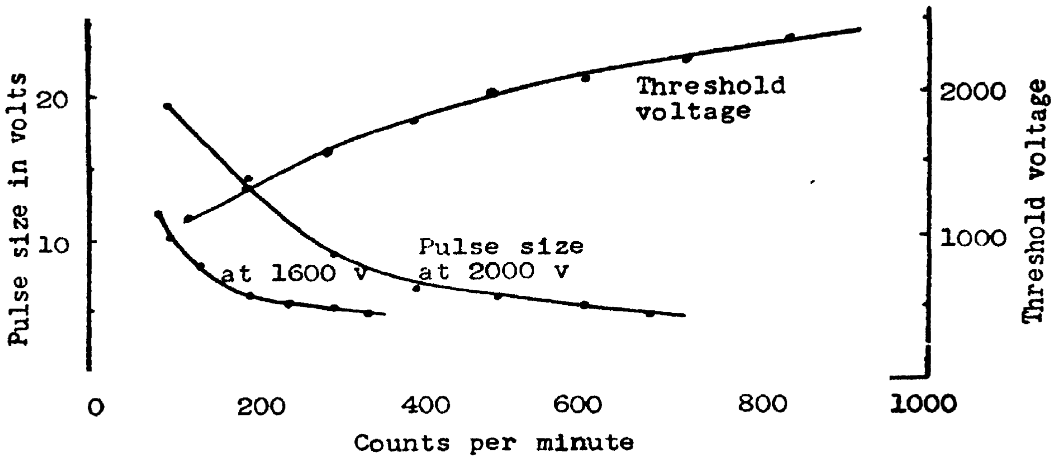

FIG. 2

The reduction in pulse size and the increment in threshold voltage observed with a scaler of 5 volts sensitivity. Same counter as used for plateau characteristic shown in Fig. 1.

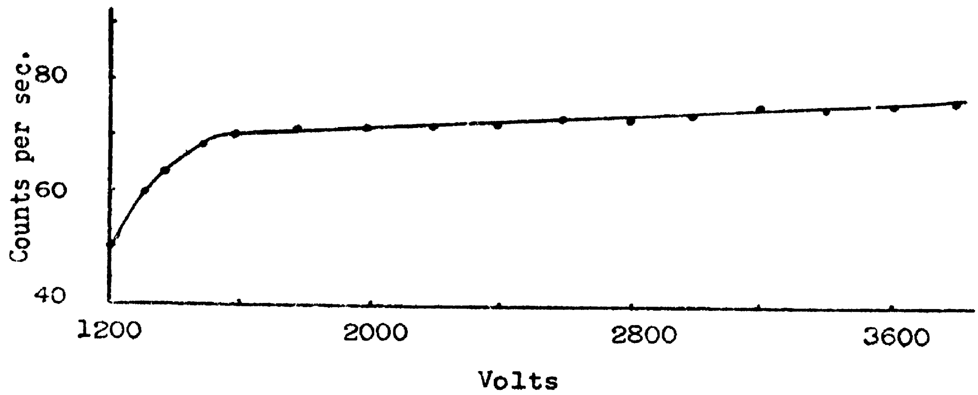

FIG. 3

The plateau characteristic of an externally coated pyrex counter with higher rate of counting. The counts were obtained from a beta ray source, and a single tube pre-amplifier was used at the input of the scaler whose sensitivity was 5 volts. This counter was different from the one used for Fig. 1 but its dimensions were the same.

becomes quite high, the pulse size, instead of continuing to diminish, becomes more or less stabilized. As can be expected, the use of a pre-amplifier to increase the sensitivity of the scaler brings the threshold voltage almost to its original value. The counter is thus capable of efficiently recording radiations producing up to several thousand impulses per minute. Fig. 3 gives a curve of the tube's performance when the rate of counting is high.

Dead time

The dead time of the counter, measured by the trigger method suggested by Stever (1942), was found to be about 3×10^{-4} sec. This does not compare too unfavourably with dead times of the order of 2×10^{-4} sec generally reported for internal cathode counters, and indicates that there is no reason to consider the new counter to be inherently much slower than the conventional ones.

TENTATIVE THEORY OF OPERATION

The difference in the mode of operation of the externally coated counters and those which have internal cathodes can be explained by putting three questions, namely, (1) Why does pulse size decrease with greater strength of incident radiation ? (2) Why is the slope so small ? (3) Why is the plateau so long ? In order to answer these questions it is appropriate to mention briefly the discharge mechanism and the action of the quenching gas in conventional counters.

When an ionizing particle passes through the counter it leaves some ion pairs, and from these pairs electrons start moving towards the central wire. As they proceed into the region of intense electric field, the energy of the electrons rapidly increases and they produce further ionisation by collision. This avalanche spreads along the length of the wire by photon action and leaves positive ions in the form of a sheath all round the central wire. Due to the presence of this sheath between the anode and the cathode, the field in the anode region is reduced beyond the threshold value so that no further ionising event can produce another avalanche before the sheath has had a chance to move out towards the cathode by a certain critical distance. The photons which are formed by recombination of a certain number of ions are absorbed by the quenching polyatomic gas and spurious counts are avoided.

The quenching gas chosen is such that its ionising potential is lower than that of the noble gas used in filling the counter. On account of this fact the positive ions of the noble gas pass their ionization on to the molecules of the polyatomic gas. Again, photons released in this process are absorbed by the quenching gas, and finally it is the positive ions of the polyatomic gas that reach the cathode. When this ion sheath reaches within about 10^{-7} cm of the cathode, electrons are taken out from the latter for neutralizing the ions. Photons are not emitted in this process because energised polyatomic molecules dissociate within about 10^{-13} sec. (for alcohol), that is, before they can emit photons which require about 10^{-8} sec. This is the most important function of the quenching gas and is responsible for the plateaus in conventional counters.

In the case of external cathode counters the ion sheath is not able to approach within 10^{-7} cm of the cathode and therefore, instead of being neutralized, a good part of it stays on the surface of hard glass. Very soon, at a particular counting rate, a balance is reached between the rate of accumulation and the rate of neutralization, resulting in the stabilization of the surface sheet of charge. This results in the reduction of the effective voltage on the counter and is responsible for the extraordinarily long plateau. When the average rate of counting increases, the sheath becomes even more positive and thus reduces the size of the pulses that are transmitted to the counting system. It has already been explained in a previous section how this can be overcome either by increasing the applied voltage or by using a pre-amplifier at the input of the scaler.

In conventional counters the plateau comes to an end when spurious counts increase enormously and discharge becomes self-maintained. These spurious counts are produced by unquenched photons formed either during recombination or during the process of neutralization of the ion sheath. In the external cathode counters photons have to pass through a region of ionized polyatomic gas molecules before they can reach the glass surface. This increases the probability of absorption of the photons and makes the slope of the plateau so small.

The idea of the formation of a surface layer is supported by other observations such as :

(1) the plateau is shorter in a freshly filled counter than in one which has been used for some time,

(2) when voltage is suddenly brought down from a high value to the threshold voltage, counts are only observed a few seconds after this change has taken place.

Further investigation is being carried out on this counter but it now appears certain that this type of counter has considerable advantages over the conventional one, since it is rugged and cheap and can be operated with inexpensive unregulated high voltage supplies.

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